Building with Tilt-Up

Lessons learned from a recent RED HORSE project

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"Tilt-up" concrete construction is a growing trend in civilian industry where functional, cost-effective structures that can be erected quickly are needed. The method may also turn out to be a viable contingency construction alternative for Air Force civil engineers.

Members of the 820th RED HORSE Squadron used it recently to construct a quarry maintenance facility at Nellis Air Force Base, NV, to validate tilt-up as a contingency construction method for airfield warehouses and maintenance buildings. The $278,000 facility includes an open maintenance bay, a secure tool storage area, administrative offices and restrooms — greatly enhancing the quality of quarry operations training.

What is Tilt-Up?

Tilt-up construction is the process of casting wall panels horizontally on a building floor slab or separate casting slab(s) then lifting or "tilting" them into place. The erected panels are temporarily braced, and then the roof structure is attached to the wall panels.

820th RHS members used the tilt-up method to construct a quarry maintenance facility on Nellis AFB. *(Photos courtesy 820th RHS)*

Tilt-up construction was first used in the early 1900s to construct warehouses, churches and factories. Today, tilt-up is used as a construction alternative to steel and wood frame, masonry and pre-engineered metal buildings. It is primarily used to build low-rise commercial and industrial buildings.

The main *Advantages* of tilt-up construction are:

- Economical construction
- Wide variety of exterior finishes
- Expandability
- Durability and low maintenance costs
- Splinter protection

The main *Disadvantages* are:

- Lack of qualified personnel and contractors
- Weight of panels on certain soils
- Available space to cast panels
- Availability of lifting equipment

Design

The seven major design steps for the quarry maintenance facility were site layout, foundation requirements, panel thickness, panel reinforcing, panel connections, roof structure and crane requirements.

Site layout: Any tilt-up site must be large enough to allow movement of transit mixers during wall panel casting and large enough for a crane to work around when lifting panels. To meet this requirement, a 6,000-square foot area was chosen for the 30- by 60-foot building footprint, parking, storage and maneuverability of equipment during construction. In addition to the building footprint, three "auxiliary" casting slabs were needed because all 16 of the wall panels could not be cast on the building floor slab.

Foundation requirements: A soil bearing capacity calculation was performed to determine the width and depth of the foundation.

Panel thickness: The wall panels were designed to be 6 inches (nominal) thick. This was done to keep their weight to a minimum while leaving them thick enough for reinforcing bars (rebar).

Panel reinforcing: The design called for #4 rebar to be placed 12 inches center-to-center, horizontally and vertically.

Panel connections: Each panel would have splice plates placed at the upper sections. The splice plates tie the building together. A welded metal plate would secure the panels to each other.

Roof structure: A standard steel K joist was designed for the building. The design was subject to standard loads listed in American Society of Civil Engineers (ASCE) 7-98, *Minimum Design Loads for Buildings and Other Structures*. The roof was designed with a standard 1.5- by 12-inch slope. The joists were selected from the economy table in *Steel Joists and Joist Girders*, a manual by the New Columbia Joist Company.

Crane requirements: Crane size is based on the weight of the heaviest wall panel. At a minimum, the crane should be sized at twice the weight, in pounds, of the heaviest panel. This is a requirement because the panels must be lifted and set into place, which creates large moments on the crane. The heaviest wall panel for the quarry facility weighed 14,600 pounds. Thus, a 15-ton crane was needed. However, to account for the reach needed to lift wall panels from the floor slab and three auxiliary casting slabs at different positions around the site, a 65-ton crane was rented.

Construction Procedure

The six major construction steps for the quarry maintenance facility were the foundation, floor slab, auxiliary casting slabs, formwork, tilt-up and roof structure.

Foundation: The building foundation was constructed using a 2-foot-wide by 2.5-foot-deep earthen footer. Six inches of Type II base course was placed at the bottom of the footer as a drainage layer. Then, Type IV Portland Cement concrete with a compression strength of 3,500 psi and at a 5-inch slump was placed into the forms. The concrete was then hand finished.

Floor slab: The floor slab is 6 inches thick with #4 rebar set in a 12-inch grid. The rebar was extended past the edges of the floor slab 24 inches to overlap with the wall reinforcement when the 3-foot closure strip was poured.

Auxiliary casting slabs: Three auxiliary slabs were built to cast eight panels. The auxiliary slabs are now used as parking space.

Formwork/bond breaker: The formwork for the wall panels must be as square as possible. Once the formwork is complete, a bond breaker is sprayed on the concrete floor slab. The bond breaker ensures the concrete wall panels do not adhere to the concrete floor or auxiliary casting slabs. After bond breaker was sprayed, rebar was placed around all door and window openings. Architectural reveals, pick points and brace points were also placed at this time. In addition, the splice plates and joist bearing plates were set in the formwork. The plates are an integral part of the concrete panels. Five-inch shear studs were connected to the plates and cast into the concrete panels.

Tilt-Up: The panels were laid out in the order of their erection. They were then lifted starting at one corner of the floor slab and working around the building until finished. As seen from the photos, the braces are quite congested in the middle. It was found that removing one of the braces from the corner panels facilitated lifting the panel. Once the panel was in place, the brace was reconnected.

Wall panels were cast horizontally then tilted into place. They were temporarily braced until the roof structure was in place.

A crane was used to set the steel joists for the roof in place.

Roof: Fourteen 20K4 joists with horizontal bridging were installed, using a crane to set them. G60 roof decking was then welded to the joists. A 1.5-inch-thick rigid insulation was placed on top of the decking, while 12-inch-wide, multi-rib panels completed the roof structure.

Lessons Learned

Pick points/brace points: When placing the concrete for the wall panels, one person must watch the pick points to ensure alignment is not offset. This is extremely critical because the panels cannot be lifted without the pick points. This is also true for the brace points. Make sure the brace points are set correctly and that both pick and brace points are capped so they do not fill with concrete when pouring the concrete for the panels.

Corner bracing: Since the quarry facility is so small, the bracing at the corners was extremely congested. Therefore, to ease brace installation, the inside brace was removed before the panel was set into place. One brace was locked into place after the panel was set, and the second brace was set before the pick points were released.

Reveals and bond breaker: Reveals must be placed in the panel forms before the bond breaker is sprayed. If the reveals are not set properly, the mistakes will be reflected in the panel and adversely affect the aesthetics.

Summary

Tilt-up construction is an economical and efficient way of constructing a facility. It offers a viable contingency construction alternative to masonry and pre-engineered buildings.

The 820th RHS is working on standard panels for buildings — a standard wall panel, a panel with window openings, a panel with door openings, and a panel with larger openings for vehicle maintenance. The standard panels will have a list of materials with brace and pick points already designed. From there, all that is required is to meet with the user to determine requirements. Once the overall requirements are known, the roof structure is designed and materials can be ordered. Then construction can begin.

Capt Peter P. Feng, 820th RED HORSE Squadron, Nellis AFB, NV, was the officer-in-charge during this project.